Project : ______________________ Prep'd by: ______________ Date : ______________

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This spreadsheet illustrates the design check of helical stair at ...

Reference : Reinforced Concrete Designer's Handbook - C.E.Reynolds and J.C.Steedman - 25.2 Stairs

Materials Concrete $f_{cu} := 30MPa$ Reinforcement $f_y := 390MPa$

$f_{yv} := 235MPa$

Cross section $h := 200mm$: depth of section $d := h - \left(40 + 16 + \frac{16}{2}\right)mm$

$b := 2500mm$: width of stair $d = 136\,mm$

$R_i := 1000mm$: internal radius $d1 := b - \left(40 + 10 + \frac{16}{2}\right)mm$

$R_o := 3600mm$: external radius $d1 = 2442\,mm$

Load calculation

Dead load

Concrete slab $g_{slab} := \frac{h}{m} \cdot 24kPa$ $g_{slab} = 4.8\,kPa$

Steps $g_{step} := \frac{100mm}{m} \cdot 24kPa$ $g_{step} = 2.4\,kPa$

$g := g_{slab} + g_{step}$ $g = 7.2\,kPa$

Live load

$q := 4kPa$

ULC

$w := 1.4 \cdot g + 1.6 \cdot q$ $w = 16.48\,kPa$

for helical stair of 2.6m width

$W := 2.6m \cdot w$ $W = 42.85\,\frac{kN}{m}$

Design moment, shear and torsion

$\beta := 250deg$ $\frac{b}{h} = 12.5$

$\phi := 20deg$

Radius of centerline of loading

$$R_1 := \frac{2}{3}\frac{\left(R_o^{\,3} - R_i^{\,3}\right)}{\left(R_o^{\,2} - R_i^{\,2}\right)}$$ $R_1 = 2.54\,m$

Radius of centerline of steps

$$R_2 := \frac{1}{2}\left(R_i + R_o\right)$$ $R_2 = 2.3\,m$

$\frac{R_1}{R_2} = 1.11$

We choose the chart table 177 (Reinforced Concrete Designer's Handbook - C.E.Reynolds and J.C.Steedman) using strain-energy principles to get the moments and force via k1, k2, k3 parameters

$k_1 := -0.17$ $k_2 := 2.12$ $k_3 := -0.42$

Redundant moment acting tangentially at midspan

$M_0 := k_1 \cdot W \cdot R_2^{\,2}$ $M_0 = -38.53\,kNm$

Horizontal redundant force at midspan

$H := k_2 \cdot W \cdot R_2$ $H = 208.93\,kN$

Vertical moment at supports

$M_{vs} := k_3 \cdot W \cdot R_2^{\,2}$ $M_{vs} = -95.2\,kNm$

At support

$\theta := \frac{\beta}{2}$ $\theta = 125\,deg$

Lateral moment

$$M_n := M_0 \cdot \sin(\theta) \cdot \sin(\phi) - H \cdot R_2 \cdot \theta \cdot \tan(\phi) \cdot \cos(\theta) \cdot \sin(\phi) - H \cdot R_2 \cdot \sin(\theta) \cdot \cos(\phi) \ldots + W \cdot R_1 \cdot \sin(\phi) \cdot \left(R_1 \cdot \sin(\theta) - R_2 \cdot \theta\right)$$

$M_n = -415.22\,kNm$

Torsional moment

$$T := \left(M_0 \cdot \sin(\theta) - H \cdot R_2 \cdot \theta \cdot \cos(\theta) \cdot \tan(\phi) + W \cdot R_1^{\,2} \cdot \sin(\theta) - W \cdot R_1 \cdot R_2 \cdot \theta\right) \cdot \cos(\phi) \ldots + H \cdot R_2 \cdot \sin(\theta) \cdot \sin(\phi)$$

$T = 10.07\,kNm$

Vertical moment

$$M_y := M_0 \cdot \cos(\theta) + \left(H \cdot R_2 \cdot \theta \cdot \tan(\phi) \cdot \sin(\theta)\right) - W R_1^{\,2} \cdot (1 - \cos(\theta))$$

$M_y = -102.02\,kNm$

Thrust

$N := -H \cdot \sin(\theta) \cdot \cos(\phi) - W \cdot R_1 \cdot \theta \cdot \sin(\phi)$ $N = 0.001\,kN$

Lateral shearing force across stair

$V_n := W \cdot R_1 \cdot \theta \cdot \cos(\phi) - H \cdot \sin(\theta) \cdot \sin(\phi)$ $V_n = 165.02\,kN$

Radial horizontal shearing force

$V_h := H \cdot \cos(\theta)$ $V_h = -119.84\,kN$

Design of edge tension reinforcement

Ultimate resistant moment	$M_u := 0.156 f_{cu} \cdot h \cdot d1^2$	$M_u = 5581.71\,kNm$
Design moment	$M := 500kNm$	$M = 500\,kNm$
	$Check_M := \begin{cases} \text{"OK"} & \text{if } M_u \geq M \\ \text{"Redesign"} & \text{otherwise} \end{cases}$	$Check_M = \text{"OK"}$
	$K := \dfrac{M}{f_{cu} \cdot h \cdot d1^2}$	$K = 0.01$
	$z_{cal} := d1 \cdot \left[0.5 + \sqrt{\left(0.25 - \dfrac{K}{0.9}\right)}\right]$	$z_{cal} = 2.4 \times 10^3\,mm$
	$z_{lim} := 0.95d1$	$z_{lim} = 2319.9\,mm$
	$z := \begin{cases} z_{lim} & \text{if } z_{cal} > z_{lim} \\ z_{cal} & \text{otherwise} \end{cases}$	$z = 2.3 \times 10^3\,mm$
Area of reinforcement	$A_{req} := \dfrac{M}{0.95 \cdot f_y \cdot z}$	$A_{req} = 581.7\,mm^2$
Provide	$A_{prov} := 3T20$	$A_{prov} = 942\,mm^2$
Reinf ratio	$A_{ratio} := \dfrac{A_{prov}}{b \cdot h}$	$A_{ratio} = 0.19\,\%$
Check ratio	$Check_{ratio} := \begin{cases} \text{"OK"} & \text{if } \left[\left(A_{ratio} \geq 0.13\%\right) \wedge \left(A_{ratio} \leq 4\%\right)\right] \\ \text{"Not OK"} & \text{otherwise} \end{cases}$	$Check_{ratio} = \text{"OK"}$

Design of tension reinforcement

Ultimate resistant moment	$M_u := 0.156 f_{cu} \cdot b \cdot d^2$	$M_u = 216.4\,kNm$
Design moment	$M := 103kNm$	$M = 103\,kNm$
	$Check_M := \begin{cases} \text{"OK"} & \text{if } M_u \geq M \\ \text{"Redesign"} & \text{otherwise} \end{cases}$	$Check_M = \text{"OK"}$
	$K := \dfrac{M}{f_{cu} \cdot b \cdot d^2}$	$K = 0.07$
	$z_{cal} := d \cdot \left[0.5 + \sqrt{\left(0.25 - \dfrac{K}{0.9}\right)}\right]$	$z_{cal} = 123.7\,mm$
	$z_{lim} := 0.95d$	$z_{lim} = 129.2\,mm$

$z := \begin{cases} z_{lim} & \text{if } z_{cal} > z_{lim} \\ z_{cal} & \text{otherwise} \end{cases}$ $z = 123.7\,mm$

Area of reinforcement $A_{req} := \frac{M}{0.95 \cdot f_y \cdot z}$ $A_{req} = 2248.1\,mm^2$

Provide $A_{prov} := 12T16$ $A_{prov} = 2412\,mm^2$

Reinf ratio $A_{ratio} := \frac{A_{prov}}{b \cdot h}$ $A_{ratio} = 0.48\%$

Check ratio $Check_{ratio} := \begin{cases} \text{"OK"} & \text{if } [(A_{ratio} \geq 0.13\%) \wedge (A_{ratio} \leq 4\%)] \\ \text{"Not OK"} & \text{otherwise} \end{cases}$

$Check_{ratio} = \text{"OK"}$

Shear reinforcement

Design shear $V_f := 226kN$:at the face of the support

$V_d := 226kN$:at distance d from face of support

Average shear stress $\nu_f := \frac{V_f}{b \cdot d}$ $\nu_f = 0.66\,MPa$

$\nu_d := \frac{V_d}{b \cdot d}$ $\nu_d = 0.66\,MPa$

Limitting shear $\nu_{lim} := \max\left(5MPa, 0.8 \cdot \sqrt{\frac{f_{cu}}{MPa}} \cdot MPa\right)$ $\nu_{lim} = 5\,MPa$

Check shear $Check_{\nu} := \begin{cases} \text{"OK"} & \text{if } \nu_f \leq \nu_{lim} \\ \text{"Not OK"} & \text{otherwise} \end{cases}$ $Check_{\nu} = \text{"OK"}$

Concrete shear capacity $k_1 := \min\left(\frac{100A_{prov}}{b \cdot d}, 3\right)$ $k_1 = 0.71$

$k_2 := \max\left(1, \frac{400mm}{d}\right)$ $k_2 = 2.94$

$\nu_c := \frac{0.79}{1.25} \cdot k_1^{\frac{1}{3}} \cdot k_2^{\frac{1}{4}} \cdot \left(\frac{f_{cu}}{25MPa}\right)^{\frac{1}{3}} \cdot MPa$ $\nu_c = 0.78\,MPa$

$Check_{link} := \begin{cases} \text{"Nominal link"} & \text{if } \nu_d \leq \frac{\nu_c}{2} \\ \text{"Design for link"} & \text{otherwise} \end{cases}$ $Check_{link} = \text{"Design for link"}$

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Calcualte shear capacity of section

$A_{sv} := 2 \cdot R10$:area of links at a section

$s_v := 150mm$:link spacing

$$V_n := \left(\frac{A_{sv}}{s_v} \cdot 0.95 \cdot f_{yv} + b \cdot \nu_c\right) \cdot d$$

$V_n = 298.5 kN$

Check shear

$$Check_{shear} := \begin{cases} \text{"safe"} & \text{if } V_d \le V_n \\ \text{"Redesign"} & \text{otherwise} \end{cases}$$

$Check_{shear} = \text{"safe"}$

Torsional resistance

Design Torsion $T_{tor} := 12kNm$

Check torsion reinforcement

$h_{min} := \min(b, h)$ $h_{min} = 200 mm$

$h_{max} := \max(b, h)$ $h_{max} = 2500 mm$

Shear stress induced by torsion

$$v_t := \frac{2T_{tor}}{h_{min}^2 \cdot \left(h_{max} - \frac{h_{min}}{3}\right)}$$

$v_t = 0.25 MPa$

Limiting torsional shear stress

$$v_{tmin} := \min\left(0.67\sqrt{\frac{f_{cu}}{MPa}}, 0.4\right) \cdot MPa$$

$v_{tmin} = 0.4 MPa$

$$Check_{torsion} := \begin{cases} \text{"provide torsion reinf"} & \text{if } v_t \ge v_{tmin} \\ \text{"torsional reinf not required"} & \text{otherwise} \end{cases}$$

$Check_{torsion} = \text{"torsional reinf not required"}$

Distance to center of links $t := (40 + 10)mm$

Link dimensions $x_1 := b - 2t$ $y_1 := h - 2t$

Torsional resistance

$$T_r := 0.8 \cdot \left(\frac{A_{sv}}{s_v} \cdot x_1 \cdot y_1 \cdot 0.95 f_{yv}\right)$$

$T_r = 44.86 kNm$

$$Check_T := \begin{cases} \text{"safe"} & \text{if } T_{tor} \le T_r \\ \text{"reduce spacing of links s.v"} & \text{otherwise} \end{cases}$$

$Check_T = \text{"safe"}$

Check torsion combined with bending and shear stress

Total shear $v := v_t + \nu_f$ $v = 0.91 MPa$

$$Check_{combined} := \begin{cases} \text{"re-design"} & \text{if } v \ge \min\left(0.8\sqrt{\frac{f_{cu}}{MPa}}, 5\right) \cdot MPa \\ \text{"safe"} & \text{otherwise} \end{cases}$$

$Check_{combined} = \text{"safe"}$